Decomposing and Reassembling Energy Grids as Socio–Technical Apparatuses

Dario PADOVAN[*a] and Osman ARROBBIO[a]

[a] Università di Torino

This contribution is aimed to provide a deeper and more complex frame for the energy smart grid implementation. To accomplish this task, we use two main perspectives. The first one is to conceive energy grids as technological zones, in which standard metering, communication infrastructures, and social evaluation assemble. The second one is to conceive energy grids as an apparatus in which asymmetries of many kinds constitute the ontology of the grid itself.

***Keywords**: Energy grids; smart grids; apparatuses*

Introduction

Smart grids are tools that can make imaginable the management of 'direct interaction and communication among consumers, households or companies, other grid users and energy suppliers' (European Commission, 2011). A smart grid allows for savings, allows for good and real–time information, and connects providers and users. Yet, what is still lacking in the claim for smart grid is an ontological dimension of interaction among energy, grid and human agents. In our idea, it is not enough to enunciate an amount of technical characteristics that should mark the grid and its smartness. What we are trying to do is to provide a deeper and more complex frame for the energy smart grid implementation embracing not only the technical but also human agency. To accomplish this task, we use two main perspectives. The first one is to conceive energy grids as technological zones, in which metering standards, communication infrastructures, and socio–technical evaluation bring together. The second one is to conceive energy grids as apparatuses in which asymmetric lines of

[*] Corresponding author: **Dario Padovan** | e–mail: **dpadovan@unito.it**

power, knowledge, information, decision–making, and intensity constitute the ontology of the grid itself. A smart grid that wants to align or flatten the original disparities making itself more effective must change by actualizing its creative potential. In so far as an apparatus such as an energy grid is constituted by heterogeneous components such as corporate actors, people and devices, its ordering is always unstable and challenged by the mutating conditions of environment. However, despite the fluctuating orders, everything that happens and everything that appears into the grid correlates with orders of differences: of level, temperature, pressure, tension, potential and intensity. When aligned, these differences produce new configurations between the elements of the grid. These new alignments are those that allow the grid to be smart.

The difference between a today's grid and a smart grid of the future is mainly in the grid's capability to handle higher levels of complexity in an efficient and effective way (European Commission, 2011). The EU described smart grids as 'energy networks that can automatically monitor energy flows and adjust to changes in energy supply and demand accordingly' (http://ec.europa.eu/energy/en/topics/markets–and–consumers/smart–grids–and–meters). Combining information on energy demand and supply, they can allow grid operators to better plan the integration of renewable energy into the grid and balance their networks. Smart grids also open up the possibility for consumers who produce their own energy to respond to prices and sell excess to the grid. However, despite the plethora of demonstration projects, the smart grid system is still much in the making, and there is still a gap between the ideas of the future system and the practical realisation of these ideas (Gram–Hanssen, 2009). In order to get an effective transition toward smart grids, important aspects that are so far considered merely technological have to be managed, faced, and where possible, overtaken.

The conceptual framework of this work mainly derives from, and was mainly tested against, the results of an empirical investigation carried out in Turin in 2014 and 2015. The investigation, consisting of thirty–eight interviews and three focus groups, was part of a project aimed at integrating ICT solutions (e.g. simulation and efficiency engines, data visualization tools) in the Turin district heating system. Interviews were aimed at identifying the features of the Turin district heating system through the various perspectives of the many roles that are played in it. Professionals of the energy utility and public administrators were involved into research activities as well as the building managers, energy managers and building users of a sample of both private (apartment buildings and a student residence) and public (university facilities, public offices and schools) buildings all situated in a single pilot district. While certain topics were emphasized, according to interviewees' roles and competences, discussions were in general about: their working/heating practices; the energy information and data they use/receive related to their work/consumption practices; their knowledge and perception about the functioning of the heating systems and network.

Conventional thermal grids

Elements of smartness already exist in parts of existing grids. But these elements have to be integrated and harmonized. The traditional or conventional paradigm is based on passive distribution and one way communication and flow between suppliers and consumers. This is dramatically true mainly for thermal grids. They convey energy by using water as a carrier. Water, hot or cold, is conveyed through underground hubs, to the buildings' heat exchangers and then distributed among final users. Thermal grids are not only a set of technical devices aimed at the provision of warmness or coldness, but a more complex arrangement of technical objects, practices and rules regulating and compensating the actions or conditions performed by agents. In our case, the thermal energy grid regulates and performs the comfort conditions of building users in two aspects. First, by determining provision of thermal energy and deciding costs and conditions of use. Second, by providing people with some tools in order to freely and autonomously control the energy apparatus. This latter, at least in our investigation concerning the district heating of Turin, is very limited. Set point temperatures and heating time schedules are often not controlled by the final user. Compared with electric energy grids, thermal grids are so unmanageable by the final users that we got the idea that they are still victims of a centralized and untouchable power. This condition arises obviously an asymmetry of power that is at the core of socio–technical apparatuses developed in the context of modern society. Here we provide some possible interpretation of smart grid making in order to foster an interplay of technical and social agents and agencies to reach a real smartness.

Technological zones

Thermal grids are situated socio–technical systems powered by long–distance fuels that combine hard technical infrastructures and devices with expectations of ordinary and pre–established actions and behaviours from both distributors and final users. In this sense, they need for working repetitive interactions among all human agents and technical devices involved and locally composing the grids. A thermal grid can also be understood as a technological zone that develops in extensity where differences and intensity are reduced thanks to standardized techniques, procedures, and spatial forms. Investigating the functioning of transnational economic arrangements, Barry (2006) suggests that technological zones take one or a mix of three forms:

a. metrological zones;
b. infrastructural zones;
c. zones of qualification and improvement.

Technological zones described by Barry (2006) are 'forms of space which are neither territorially bounded nor global in their extension, yet are of considerable political and economic significance'. This definition fits our idea of energy grid in the sense that even it is deployed at the rather local level, the energy flowing into it comes from different and often very globalized sites and infrastructures (Urry, 2014). However, due to the nature of our investigation, our focus is on agents acting where the grid is deployed, on a space of place 'within which differences between technical practices, procedures or forms have been reduced, or common standards have been established' (Barry, 2006). We believe that the analytical approach of 'technological zones' to investigate energy grids is plausible in order to pinpoint hotspots and difficulties in the process of smartness.

Metrological zones

At the core of smart grid is a metrological zone based on smart metering. Without a homogeneous metrological zone where power metering is standardized in order to make all agents aware of their contribution to the grid functioning, we find no smartness. When coupled with smart metering systems, smart grids reach consumers and suppliers by providing information on real–time consumption. This process is called feedback. Feedback is claimed to be a strong condition for the grid's smartness (Pullinger, Lovell and Webb, 2014). The assumption behind a smart metrological zone is that energy consumption behaviours can be altered by reminders on energy consumption data provided by ICTs devices, and that consequently behaviour can be monitored and changed where needed (Cakici and Bylund, 2014). However, the main problem still refers to the poor diffusion of data on consumption along the grids. As in the case of a primary public school that we investigated, when asked about the data used to monitor energy consumption, school manager said that she never saw any. She claimed also that she is so targeted by an information overload those data concerning energy consumption are easily lost in the overall flows of data. In short, not only public institutions often do not get comprehensive data about their consumption, but also it disperses among increasing flows of information. As claimed by the City energy manager, until a few years ago the Municipality knew anything about the consumption of their buildings. There was just a unique yearly bill with the total amount to pay. 'And that was the knowledge we had about our consumption' (City energy manager).

Infrastructural zones

The development of common connection standards makes it possible to integrate systems of provision, distribution, and communication, as well as to exclude providers and consumers who do not conform to them. Connection standards allows remote reading of meter registers by metering operators and by third parties. Moreover, these functionalities allow facility for both on–demand and frequent regular readings being available to the meter operator. The provision of meter reading information by the supplier to the customer is thus very crucial. This would include interval readings or peak demands where the tariff is based on these; ability of linking several meters (electric, gas, water, etc.) into a single Smart Meter System; correct billing. Infrastructural zones are thus zones of interoperability among different agents. It means that the thermal system must be monitored using sensors, collecting and crossing data, performing algorithms, building platforms, enabling feedback processes.

These infrastructural zones serve to make social practices of heating and cooling possibly less disordered or redundant compared to what they already are. Infrastructural zones also serve to reduce the power disparity and differential among agents, that is an ontological condition of smart energy grids. However, research on feedback effects illustrates its own limits for fostering behavioural change. In our investigation, we found that thermostatic valves, that are a very crucial metrological device and are always associated with smart grid deployment, are also a problem (at least initially) as claimed by a building manager. 'The first year [following the valves installation] someone pays double the amount they previously paid. That is because the forecast budget is based on the cubic meters of the flats [...] People don't understand. They go crazy!'. The elderly have also difficulties in managing thermostatic valves, in reading consumption, and finally in compensating the initial expense with energy saving. In short, as observed also by Hargreaves, Nye and Burgess (2010), householder's interaction with feedback is marked by contrasting aspects. On one side, overtime, smart energy devices could gradually become 'backgrounded' within normal household routines and practices, increasing the householders' knowledge of and confidence about the amount of energy they consume. On the other side, however, beyond a certain level and for a wide variety of reasons, these devices do not necessarily encourage or motivate householders to reduce their levels of consumption. Once equipped with new knowledge about their levels of energy consumption, householders soon realize the limits to their energy saving potential. Moreover, they might experience an over engagement with the device. Thus, householders progressively develop some disappointment, lose their dedication to the metrological apparatus, and become frustrated by the absence of wider policy and market support.

Zones of qualification and improvement

Smart energy grids imply the existence of a zone of assessment, in which evaluations related to the qualifying of grid and on the capacity of the grid to allow comfort while saving energy are performed. The development of common regulatory or quality standards has become critical to the government of energy. Such standards govern the quality of practices enabled thanks to energy, which may exist within a particular domain. Necessarily, such standards depend on the development of various technical devices, which make it possible to assess and compare the quality of practices performed. We may speak of the existence of a zone of qualification when the technical devices allow for practices that meet common criteria, such as environmental standards.

The problem is that, the way for facing the human scope in energy grids is mainly psychological or behavioural, what that has been termed by Elizabeth Shove the ABC (attitudes, behaviour, change) syndrome (Shove, 2010). Our exploration confirms that this is the main vision shared by designers, engineers, and different public and private energy managers. Behind this approach is the idea that individuals are fully rational beings and that they should be aware of what they are consuming and dissipating in both monetary and thermodynamic terms. Conversely, energy is for people a volatile and sometime invisible object, difficulty understandable in its nature. This makes energy management and conservation practices both difficult and unusual. The more modern energy systems provide increasingly invisible means of meeting demands for heating and cooling. Warm water that flows seamlessly and silently into homes meeting our demand of comfort makes it without any notable trace of their presence (Ehrhardt–Martinez, Donnelly and Laitner, 2010; see also Schwartz et al., 2013). The only way to get an account of energy use are the practices that people perform thanks to energy. Household's everyday practices are indicators of how much energy is consumed and dissipated, the involuntary way to make energy visible.

Socio–technical apparatuses

Technological zones are mainly technology–oriented. It is not wrong to depict energy grids in terms of technical standardization but this seems to exclude something else. Here we broaden the Foucauldian perspective suggested by Barry embracing the very interesting concept of dispositive or apparatus forged by Michel Foucault along all its oeuvre (see Agamben, 2009; Bussolini, 2010; Raffnsøe, 2008).

An apparatus is 'a thoroughly heterogeneous set consisting of discourses, institutions, architectural forms, regulatory decisions, laws, administrative measures, scientific statements, philosophical, moral, and philanthropic propositions–in short, the said as much as the unsaid. Such are the elements of the apparatus' (Foucault, 1980, p. 194). The apparatus itself is the network that can be established between these elements, but it is also an assemblage or a hybrid of technical and social elements, which has the strategic function in a given moment to respond to an urgency. Foucault refers to the apparatus as a device consisting of a series of parts arranged in a way so that they influence the scope. An apparatus indicates an arrangement that exerts a normative effect on its 'environment' because it introduces certain dispositions.

According to Foucault, there are two important moments in the apparatus's genesis. A first moment is oriented to a prevalent strategic objective. In a second step, the apparatus is constituted and enabled to continue in existence insofar as it is the site of a double process. On the one hand, there is a process of 'functional over–determination'. Each effect – positive or negative, intentional or unintentional – enters into resonance or contradiction with the others and thereby calls for a readjustment or a re–working of the heterogeneous elements that surface at various points. On the other hand, there is a perpetual process of ‘strategic elaboration’ that allows the apparatus to establish and reproduce different fields of power relations (Foucault, 1980, p. 195). Being its nature essentially strategic and teleological, it implies a certain manipulation and a rational and concrete intervention in the relations of forces, either to develop them in a particular direction, or to block, stabilize and utilize them. Finally, apparatus is also always linked to certain limits of knowledge that arise from it and, to an equal degree, condition it. In short, an energy grid is a set of strategies of the relations of forces supporting, and supported by, certain types of knowledge.

Foucault applies his concept of apparatus to asylums, prisons, schools, factories, and hospitals, as apparatuses of disciplining, normalizing, and securing practices. In our view, it appears reasonable to apply the apparatus's concept to energy grids. Norms are thus developed and inscribed into a play of power, aimed to overcome resistances, to change inertial habits and to orient future choices. Data standardization and collection is crucial to monitor the functioning of the energy grid, to drive it toward more efficient ways to provide and use energy, and to discipline agents for more appropriate behaviour. Infrastructures provide the architectural frame in which power and prescriptions flow. In the case of the energy grid, ‘functional over–determination’ refers to the interactivity between effects of constructive or destructive interaction/interference that might create a need to adjust or rework the connections between elements. A perpetual process of ‘strategic elaboration’ happens whereas the strategic objective is the reduction of energy dissipation alongside the grid. This energy grid transition is not irenic, but constellated by more or less critical contradictions that ask for perpetual adjustments. This holds for example the interest of provider to provide increasing amount of energy or the aspiration of the final user to freely use the desired amount of energy without constraints, or again the right of final users to exercise a quasi–total control on their piece of apparatus.

What we discovered is that our actors would take place inside the apparatus, cooperating in it, sharing the power circulating in it. The problem is that they cannot do it because they are ‘off–grid’, separated from the apparatus or deprived of their potential or virtual agency to act on it. Moreover, when they are incorporated into the grid, they fight with the grid's devices, that resist any intervention and intrusion. As claimed by a public building manager, he essentially tries to develop 'some friendly relations with the thermal apparatus'. He tries to enable a dialogue with it:

> 'It should not be difficult to control thermostats: it is just about setting the temperature. In reality it does not work in this way [...] The problem is that only those who have installed the implant can act on the system. We need autonomy to act directly upon the system. This is what is lacking due to the system design. Corporate policies aimed at reducing consumption have been activated, but if there is no control on the thermal system, if there is no feedback with devices, if these devices are out of user control, it is impossible to implement any energy regulation policy' (Building manager, public building).

Final users expect to be active grid supporters and not only passive objects of grid, aiming to drive and sway technological improving dynamics, as in the case of the public building managers. They also are not really persuaded to interact permanently with devices. in order to improve their performance.

This dilemma regarding practices into the grids arises a broader general question regarding the role of technical devices and artefacts in the evolution of the apparatus. Foucault mentions material arrangements as part of the apparatus, but he does not pay much interest in developing this, as it would deserve. He only alludes the ways in which technical apparatuses provide intimate, pervasive, and profound reconfiguring of practices performed by agents, and that this reconfiguring is often unstable and unfixed. The definition of apparatus provided by Deleuze sounds more fitting our idea of energy grid, underlining the disconnected and rather precarious character of such ensemble of heterogeneous elements.

> 'But what is a dispositif? In the first instance it is a tangle, a multilinear ensemble. It is composed of lines, each having a different nature. And the lines in the apparatus do not outline or surround systems which are each homogeneous in their own right, object, subject, language, and so on, but follow directions, trace balances which are always off balance, now drawing together and then distancing themselves from one another. Each line is broken and subject to changes in direction, bifurcating and forked, and subject to drifting. Visible objects, affirmations which can be formulated, forces exercised and subjects in position are like vectors and tensors. Thus the three major aspects which Foucault successively distinguishes,

> Knowledge, Power and Subjectivity are by no means contours given once and for all, but series of variables which supplant one another' (Deleuze, 1992, p. 159).

Readjusting the notion of apparatus, moving it toward a consistent materiality where the inseparability of objects and subjects is acknowledged, it can give energy grid a different interpretation, allowing the pinpoint of a surface where to attach strategy of transition. In short, a conventional energy grid is an apparatus in which humans act as depending from devices driven by incorporated knowledge and language. A smart energy grid is an apparatus in which devices and humans try to communicate to adapt to new conditions.

Transitional apparatuses as new frame for energy policy

Because of path–dependency mechanisms deployed by the development of fossil fuel conventional energy grids, the transition toward smart energy grids must start from them. A counter–apparatus, far more suitable and acceptable for current purposes of energy transition of those existing nowadays, can be built only on already existing infrastructures. Consequently, we need to know how conventional grids work and where their potential for change is. As technological zones they are rather rigid, linear, inelastic and thus useful only to a certain extent. In the case of the district heating the situation is even worst in the sense that the rigidity and path dependency of co–generation apparatuses is very strong: likely will be very tough to emancipate this energy provision from its fossil fuel primary source. Moreover, the socio–technical vision of grids transition is considerably naïf: the list of stuff that 'should be done' is not enough to ensure a successful transition.

The notion of apparatus or dispositive seems us more useful to adopt strategies of transition. This notion is similar to concepts such as assemblage (DeLanda, 2006) and arrangement (Schatzki, 2011, 2015), which outline a relational system for dissimilar elements and practices. Apparatuses, assemblages, and arrangements are concepts that often overlap, and that at the empirical level can operate symbiotically to explain the forging and emerging of practices such as energy production, distribution, usage, and dissipation. However, that of apparatus seems us a more intense, dynamic, and agential concept than the other ones. The co–evolution of varying lines and strata of practices, techniques, discourses, and singularities establishes it. An apparatus is more concerned with its security and functional certainty than an always virtual and a never fully actualized assemblage. Moreover, it is purpose–oriented in the sense that an apparatus organizes people, artefacts, enunciations, and things according to functions, statuses, and relations of agents involved in it (Schatzki, 2015). Finally, it denotes large systems of real life with a relevant time–space dimension, such as energy systems, which are incessantly changing. Regarding energy grids, it is undoubtable that they are greatly concerned with their security and continuity in time and space. They aim toward clear purposes, are spatially deployed, and they are under an incessant process of change depending on the practices performed within them.

Our approach is close to a sociology of flows as it has been suggested by Mol and Spaargaren (Mol and Spaargaren, 2005), developed on the basis of Castells and Urry seminal works (Castells, 1996; Urry, 2003). The notion of apparatus might help the development of a very challenging sociology of flows, still undertheorized, mainly from the point of view of regulation. An apparatus focuses on strategic practices aimed to cope with problems of security: spaces and technologies of security, treatments of the uncertainty, and forms of normalization of human conduct (Foucault, 2007, p. 25). In this sense, the apparatus is much more oriented toward clear goals implying a flexible management of flows than the Urry's vision for which flows have no goal or end and tend to generate via iteration complexity, instability, uncertainty (Urry, 2003). To obtain a safe circulation of people, money, commodities, energy and so on, and to secure stocks depending from flows but also generating them, an apparatus must regulate flows. In doing that it generates a circulating and securing power which, on its turn, often generates resistance, tensions, ruptures, protests. The analysis of conflicts, manipulation, and efforts to access or appropriate flows, as well as resistance to escape the regulation of flows, is matter of investigation for a sociology of flows.

The fact that human agents always belong to apparatuses and act within them, means that apparatuses exercise a certain power on them but also that agents can change them performing their own practices or fighting with them (Agamben, 2009). In other words, apparatuses change to secure their own continuity and the 'immortality of society' (Garfinkel, 1988). However, as explored by Deleuze (1992), each apparatus shows lines of breakage and fracture. Sometimes these are situated on the level of powers; at other times on the level of knowledge; other times more at the level of structures of practical action. More generally, it should be said that the lines of subjectivation indicate fissures and fractures. Change depends on the content of the apparatus, and each apparatus deserves its own diagnostic, its own archaeology. Moreover, an apparatus creates a propensity for certain types of events, a trend that some things 'happen'. The application of this concept to an energy grid opens up the possibility of its change towards the smartness. Can an apparatus become smart, flat, democratic, equal or differentiated in its functions and provisions? Might an apparatus such as a thermal grid be designed and managed in order to raise insensible but enduring changes in the agents' performance? Or to be flexible enough to change in virtue of agents' performance?

Asymmetries of energy and power

Thermal (also electric) grids are complex apparatuses of connection of different agents, equipped with different power of influence and intervention on energy flows. It is in some way self–evident the fact that big energy providers and final users are very asymmetrical in the influence on energy management. In their working, thermal grids bring and convey both energy power for heating and social power in forms of rules, norms, and dispositions. Our investigation rises up the problematic of the flows and links between energy and power as well as of the way in which their processes change the actual configurations. The agents of those processes and how their nexuses and relationships work out, become a matter of investigation. How is the power of power maintained, conditioned and disputed by coalitions of agents, dominant and resistant, performing different but interlinked social practices from which these emerge? (Mitchell, 2011). This asks for analysis of how power flows through complex systems, how it supports and makes existing positive and negative feedback loops between production and consumption of energy, how technical devices, knowledge, enunciations, build up energy machines, regimes, apparatuses, that make society likely. Social forms, as living systems, depend upon flows of energy maintaining their systemic viability far from thermodynamic equilibrium (Smil, 2010). Since only the simplest forms of energy may be harnessed without infrastructures, energy resources are always mediated through socio–technical systems (Smil 2010, p. 12) and human labour that give them a particular social configuration in order to make apparatuses working. Energy and its carriers are basic commodities that are essential in the production of all commodities (including labour power). Energy keeps different forms aimed to sustain the metabolic reproduction of a number of different social subsystems and agents (Padovan, 2015a; 2015b; Padovan, Martini and Cerutti, 2015).

In their effectiveness, energy networks are analogous to social networks, been made of the same substance: a variable and disparate assemblage of natural, technical, and social elements, a continuous process fostering differences and repetitions. As in the social networks, in which power flows reproducing asymmetries and differences (but also negating them), in these technical networks energy flows reproduce asymmetries and dissimilarities. The analogy can go further whereas we pinpoint dynamics of energy/power circulation, security, and control: how is the grid governed? Who benefits in terms of energy provision, consumption and comfort? Is the smart energy grid a dispositive that assures a win–win mechanism? Our investigation tried to give some answers to these questions, not looking at thermal grids as a vertical apparatus going from the centre to the periphery, but understanding energy/power circulation by looking at its extremities, at its outer limits where it becomes capillary (see Foucault, 2003). For instance, we discovered continuous attempts made by final users to understand how much they are consuming, how to save energy, how to regulate temperature, how to intervene on devices, how to make the apparatus more flexible.

Conclusions

Our goal, inspired by Foucault and Deleuze, has been to analyse energy/power regulation at the point where it is invested in real and effective practices, where it relates directly to what we might call its object, its target, its field of application, or, in other words, the places where it produces its real effects (Foucault, 2003, p. 28). Rather than asking ourselves who simply rules or governs the grid, we should try to discover how multiple bodies, forces, objects, desires, thoughts, are gradually and materially constituted as subjects in the making of the thermal grid. It might be a matter for a renewed sociology of flows because, for instance, we realized that conventional grid leaves agents in a state of blindness regarding the heating system functioning. On the other hand, the deployment of smart grids implies a process of subjectivation whereas agents are invested by a twofold dynamic of freedom and individual responsibility. Together with water, grid also conveys data, prescriptions, rules, and codes, aimed to discipline and regulate users' practices, from connection to payment. Agents can bend, made some conditions, the grid toward their own goals, or can refuse at all the regulating power conveyed by it. Forms of adaptation, rejection and manipulation constellate the grid, becoming sources of controversies and conflicts mainly in buildings where different tenants experience different intensities and performances of the grid, or in different areas where grid shows some malfunction. Finally, the transition process towards the smartness is often, if not always, seen as a simple addition of different technical operations. From our point of view, these operations are too naïf, socially inappropriate, and driven by a mechanic and linear causality. We suggest thinking in terms of apparatus, assemblage, bundle of practices and arrangements qualified by circularity and co–evolution.

References

Agamben, G. (2009) *What is an Apparatus*? Stanford: Stanford University Press.

Barry, A. (2006) Technological Zones. *European Journal of Social Theory*. 9 (2), 239–253.

Brounen, D., Kok, N. and Quigley, J.M. (2012) Residential Energy Use and Conservation: Economics and Demographics. *European Economic Review*. 56 (5), 931–945.

Bussolini, J. (2010) What is a Dispositive? *Foucault Studies*, 10, 85–107.

Cakici, B. and Bylund, M. (2014) Changing Behaviour to Save Energy: ICT–Based Surveillance for a Low–Carbon Economy in the Seventh Framework Programme. In *Proceedings of the 2014 conference ICT for Sustainability*.

Castells, M. (1996) *The Rise of the Network Society. The Information Age: Economy, Society, and Culture, Volume 1*. Malden: Wiley–Blackwell.

Crockett, C. (2013) *Deleuze beyond Badiou. Ontology, Multiplicity and Event*. New York: Columbia University Press.

DeLanda, M. (2006) *A New Philosophy of Society*. London: Continuum.

Deleuze, G. (1992) What is a Dispositif? In Armstrong, T.J. (ed.), *Michel Foucault Philosopher*. New York. Routledge.

Deleuze, G. (1994) *Difference and Repetition*. New York: Columbia University Press.

Ehrhardt–Martinez, K., Donnelly, K. and Laitner, J.A. (2010) *Advanced Metering Initiatives and Residential Feedback Programs: A Meta–Review for Household Electricity–Saving Opportunities*. Washington DC: ACEEE.

European Commission (2011), *Definition, Expected Services, Functionalities and Benefits of Smart Grids*. Accompanying documents to communication from the commission to the European Parliament, the Council, the European economic and social committee and the committee of the Regions, 'Smart Grids: From Innovation to Deployment', com (2011) 202 final Brussels, 12.4.2011 sec (2011) 463 final.

European Environment Agency (2013) *Achieving Energy Efficiency through Behaviour Change: What Does it Take?*. EEA Technical report No 5/2013.

Foucault, M. (1980) *Power/Knowledge: Selected Interviews and Other Writings, 1972–1977*. New York: Pantheon Books.

Foucault, M. (2003) *Society Must Be Defended. Lectures at the Collège de France, 1975–76*. New York: Picador.

Foucault, M. (2007) *Security, Territory, Population, Lectures at the Collège de France, 1977–78*. London: Palgrave MacMillan.

Garfinkel, H. (1998) Evidence for Locally Produced, Naturally Accountable Phenomena of Order, Logic, Reason, Meaning, Method, etc. In and as of the Essential Quiddity of Immortal Ordinary Society, (I of IV): An Announcement of Studies. *Sociological Theory*, 6 (1) 103–109.

Gram–Hanssen, K. (2009) Standby Consumption in Households Analysed with a Practice Theory Approach. *Journal of Industrial Ecology*, 14, 150–165.

Hargreaves T., Nye, M. and Burgess, J. (2010) Making Energy Visible: A Qualitative Field Study of How Householders Interact with Feedback from smart Energy Monitors. *Energy Policy*, 38 (10), 6111–6119.

Mitchell, T. (2011) *Carbon Democracy*. London: Verso.

Mol, A.P.J. and Spaargaren, G. (2005) From Additions and Withdrawals to Environmental Flows: Reframing Debates in the Environmental Social Sciences. *Organization & Environment*, 18 (1), 91–107.

Padovan, D. (2015a) Assembling Societal Metabolism and Social Practices: The Dynamics of Sustainable and Unsustainable Reproduction. In Strandbakken, P. and Gronow, J. (eds.), *The Consumer in Society. A Tribute to Eivind Sto*. Oslo: Abstrakt Forlag AS.

Padovan, D. (2015b) Metabolic Exchanges and Practices of Regulation. The Assemblage of Environment and Society in Early Social Sciences. *Ecological Informatics*, 26 (1), 6–17.

Padovan, D., Martini, F. and Cerutti A.K. (2015) Social Practices of Ordinary Consumption: An Introduction to Household Metabolism. *Journal of Socialomics*, 4 (2), 1–11.

Pullinger, M., Lovell, H. and Webb, J. (2014) Influencing Household Energy Practices: A Critical Review of UK Smart Metering Standards and Commercial Feedback Devices. *Technology Analysis & Strategic Management*, 26 (10), 1144–1162.

Raffnsøe, S. (2008) Qu'est–ce qu'un dispositif? L'analytique sociale de Michel Foucault. *Revue canadienne de philosophie continentale*, 12, 44–66.

Schatzki, T. (2011) Where the Action Is. Sustainable Practices Research Group. Working Paper 1, University of Lancaster. [Online] Available from: http://www.sprg.ac.uk/uploads/schatzki–wp1.pdf [Accessed: August 2nd, 2017].

Schatzki, T. (2015) Spaces of Practices and of Large Social Phenomena. *EspacesTemps.net*. [Online] Available from: http://www.espacestemps.net/articles/spaces–of–practices–and–of–large–social–phenomena/ [Accessed: August 2nd, 2017].

Schmidt, R.–R., Fevrier, N. and Dumas, P. (2013) *Key to Innovation Integrated Solution. Smart Thermal Grids*. European Commission, Smart Cities and Communities.

Schwartz, T., Stevens, G., Ramirez, L. and Wulf, V. (2013) Uncovering Practices of Making Energy Consumption Accountable: A Phenomenological Inquiry. *ACM Transactions on Computer–Human Interaction*, 20 (2), 12.

Shove, E. (2010) Beyond the ABC: Climate Change Policy and Theories of Social Change. *Environment and Planning*, 42 (6), 1273–1285.

Smil, V. (2010) *Energy Transitions*. Santa Barbara: Praeger.

Urry, J. (2003) *Global complexity*. Cambridge: Polity.

Urry, J. (2014) The Problem of Energy. *Theory, Culture & Society*, 31 (5), 1–18.